Reviews

Report on the Origin, Geological Relations and Composition of the Nickel and Copper Deposits of the Sudbury Mining District, Ontario, Canada. By A. E. BARLOW. (Annual Report of the Canadian Geological Survey, Vol. XIV. Part H, 1904.) With geological maps.

Dr. Barlow publishes in this report the results of his careful and exhaustive study on the Sudbury nickel district of Ontario. He makes the succession as follows:

1. *Lower Huronian.*—No rocks of this age are at present known in the nickel-bearing area, but this period is represented, in part, by the banded siliceous magnetites and associated rocks of the townships of Hutton and Wissner.

2. *Upper Huronian.*—(A) Diorites, hornblende-porphyrites, and green schists; (B) conglomerates, graywackes, and quartzites; (C) norite and diorite (Worthington mine belt, and areas southeast of Evans mine and east of Sudbury).

3. *Laurentian.*—Granite and diorite-gneiss near Wahnapitae station.

4. *Upper Huronian* (?).—Tuffs, felspathic sandstones, and slates classified provisionally on previous geological maps as of Cambrian age.

5. *Post-Huronian.*—(A) Granites; (B) nickel-bearing eruptive of the main belt (quartz-hypersthene-gabbro or norite, diorite, with their peculiar differentiation product, micropegmatite). (C) dykes of olivine diabase.

On the accompanying maps the rocks are separated lithologically and are all bracketed under the general heading "Archean." All of these terms are used in the sense commonly given them by the Canadian Geological Survey. The district is closely related with the Lake Superior region on the west, and there the U. S. Geological Survey uses different terms for what are believed to be equivalent series. Barlow's Lower Huronian may be correlated with the Archean of the U. S. Geological Survey; Upper Huronian, with the U. S. Geological Survey Lower Huronian; Laurentian, with the granites mapped as intrusive into the Huronian of the U. S. Geological Survey; Upper Huronian (?) with the Upper Huronian of the U. S. Geological Survey.

The nickel and copper are confined to the norite and its altered varieties. Closely associated with this is a rock of granitic composition of prevailing gneissoid texture, which cannot be sharply separated from the basic eruptive, although the change is usually sharp enough to allow of a boundary being drawn between them. The norite ranges, as shown by Coleman, are probably the exposed portions of one continuous laccolite, with occasional minor irregularities or offsets, which has been folded into a platter-shaped trough, holding in its depressed interior nearly flat-lying Huronian (?) sediments constituting the uppermost series of the district. The relations of these sedimentary rocks to the norite are in doubt, but later work seems to indicate a close relationship, both in origin and age, with the main masses of norite.

The nickel is mainly in the form as a nickel iron sulphite, pentlandite, associated with pyrrhotite and chalcopyrite. That the ore has been segregated more or less directly from magma is believed to be shown by the following facts:

The deposits, without exception, all occur at the margin of the gabbro or norite, the rock itself in immediate association with the ore being finer in texture, and relatively much more basic in composition, than portions further removed from the contact.

The sulphides are always much more sharply defined against the walls of the intrusion than on the inner side towards the main mass of the gabbro.

These deposits are always found in such intimate association with the norite or hypersthene gabbro.

Pyrrhotite, chalcopyrite, and pyrites are all ordinary constituent minerals of the normal norite, and are, at times, comparatively abundant even in exposures situated some distance from the contact.

The sulphides are, undoubtedly, of primary origin, and are among the earliest of the minerals to crystallize out from the original magma, sometimes even antedating the iron ore, in which they are occasionally completely inclosed.

The transitional type between the normal norite and the richer forms of the pyrrhotite-norite furnishes unmistakable evidence that in these cases, at least, the sulphides were formed during the cooling and crystallization of the norite magma, and that they were very little affected by any secondary action.

Secondary quartz, calcite, and dolomite are occasionally present, in appreciable amounts, but the prevailing scarcity of these minerals at most of the deposits has always been a subject of remark.

The deposits are singularly uniform in chemical and mineralogical

composition, and their monotonous character, in this respect, has been frequently commented upon.

Brecciation, which is so frequently characteristic of these deposits, is an almost constant feature of eruptive contacts, resulting from the detaching of material from the containing walls.

This conclusion is in accord also with evidence drawn from analogy with chemical and metallurgical principles.

Dr. Barlow concludes further that there can be little doubt of the abundant presence of heated solutions and vapors, which were capable of dissolving out, and, under certain conditions, redepositing these sulphides. Such agencies certainly began their work before the whole magma had cooled, bearing their heavy burdens of sulphide material, most of which was obtained from the magma in the immediate vicinity,to occupy the various cavities and fissures as fast as these were formed. The whole of this action was practically completed before the intrusion of the later dikes of the olivine-diabase, which are now regarded by Dr. Barlow as the end product of the vulcanism to which the norite masses owe their intrusion. In certain of the deposits the various hydrochemical agencies accompanying dynamic action have been more active than in others, as at the Victoria mine, and some of the Copper Cliff mines, but in others—as, for instance, the Creighton mine—magmatic differentiation has been the main and almost sole principle determining and favoring the development of this, the largest and richest sulphide nickel mine in the world.

The evidence summarized by Dr. Barlow seems to show beyond reasonable doubt that the norite is the original source of these sulphides. However, he describes evidence of redistribution by aqueous and gaseous solutions accompanying later stages of the norite eruption, and it is difficult to see how this evidence will enable one to draw any line between, or determine relative emphasis to be placed on, redistribution by such agencies and redistribution by meteoric waters heated by contact with the cooling norite or by meteoric waters acting subsequent to its cooling. Difference in emphasis on these factors now constitutes the main outstanding difference of opinion as to the origin of the ores.

The report is accompanied by a brief description of the geology of well-known nickel deposits of the world, and a summary of the metallurgical principles applicable to the extraction of nickel, making it useful as a nickel handbook. All interested in the geology of ore deposits will appreciate Dr. Barlow's adequate and satisfactory treatment of his subject.

Reference should be made to two other reports on the district which have appeared in the last two years—one by Mr. Charles W. Dickson, in

Vol. XXXIII of the *Transactions of the American Institute*, 1903, and another by Professor A. P. Coleman, in the *Annual Report of the Bureau of Mines of Ontario*, 1903. Dr. Barlow is in essential accord with Professor Coleman, though differing in details and emphasis on certain points. He differs from Mr. Dickson in putting emphasis on the magmatic segregation of the ore rather than on the secondary concentration. Dickson concludes that the preliminary concentration accompanying the intrusion of the norite was comparatively slight; that appeal must be made to a more distant source of the metals, probably minutely disseminated in the rocks through which the depositing solutions passed; and that, in general, the whole weight of the evidence points to the secondary formation of the Sudbury ore-bodies as replacements along crushed and faulted zones, with only minor indications of open cavities.

C. K. L.